NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

**ANALYZING SOLDIER IN-PROCESSING
AT THE UNITED STATES ARMY FIELD ARTILLERY
TRAINING CENTER THROUGH SIMULATION**

by

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June 1999

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Each year the United States Army in-processes thousands of new recruits at training centers. Variations in the number of recruits who arrive for in-processing, particularly surges during summer time, cause problems that ripple throughout the entire Army training base. This thesis gathers and analyzes historical recruit and in-processing data for one Army training base: Fort Sill, Oklahoma. The recruit reception process is modeled as a network flow problem and analyzed through the use of computer simulation. Analysis of the problem using the model compares the status quo to various options for improving recruit "throughput." Policy options are explored on a cost and benefit basis. Recommendations improve reception battalion "throughput" by making better use of existing resources, and establish guidelines for allocating additional resources, thus contributing to solving a significant scheduling problem for the Army Training Centers.

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ANALYZING SOLDIER IN-PROCESSING AT THE UNITED STATES ARMY FIELD ARTILLERY TRAINING CENTER THROUGH SIMULATION

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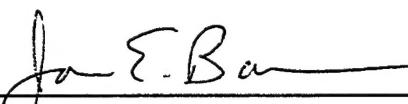
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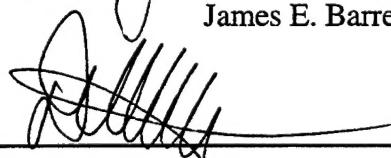
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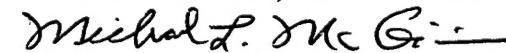
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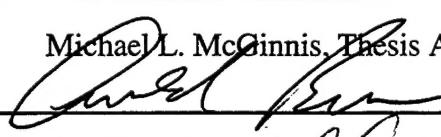
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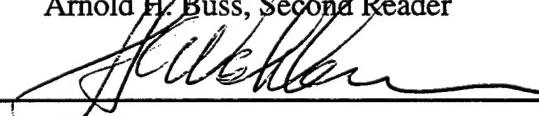
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ABSTRACT

Each year the United States Army in-processes thousands of new recruits at training centers. Variations in the number of recruits who arrive for in-processing, particularly surges during summer time, cause problems that ripple throughout the entire Army training base. This thesis gathers and analyzes historical recruit and in-processing data for one Army training base: Fort Sill, Oklahoma. The recruit reception process is modeled as a network flow problem and analyzed through the use of computer simulation. Analysis of the problem using the model compares the status quo to various options for improving recruit "throughput." Policy options are explored on a cost and benefit basis. Recommendations improve reception battalion "throughput" by making better use of existing resources, and establish guidelines for allocating additional resources, thus contributing to solving a significant scheduling problem for the Army Training Centers.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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LIST OF ACRONYMNS

AG   Adjutant General

AIT   Advanced Individual Training

BCT   Basic Combat Training

CIIP   Clothing Initial Issue Point

DEERS   Dependent Enrollment Eligibility Reporting System

FIFO   First-In-First-Out

GS   Government Service

ID   Identification (Card)

MEP   Military Entry Processing (Station)

MOS   Military Occupational Speciality

OSUT   One-Station Unit Training

PAD   Personnel Affairs Detachment

SVC   Stored Value Card

TDA   (Army) Table of Distribution and Allowances

TRADOC   (United States Army) Training and Doctrine Command

USAFATC   United States Army Field Artillery Training Center

USAREC   United States Army Recruiting Command

V&V   Verification and Validation

EXECUTIVE SUMMARY

Each year the United States Army in-processes thousands of new recruits at training centers. Processing centers, called Reception Battalions, receive and in-process these recruits. Variations in the number of recruits who arrive for in-processing, particularly surges during summer time, cause problems that ripple throughout the entire Army training base.

The United States Army Field Artillery Training Center (USAFATC) at Fort Sill, Oklahoma is one of five Army Training Centers with a Reception Battalion. The Commander, USAFATC, directed a study of options to increase throughput of soldiers through its Reception Battalion. The reception process may be viewed as a network of sequential service stations that new soldiers must visit to accomplish tasks prior to beginning basic combat training. In-processing stations include medical, dental, optical, clothing issue, and administrative paperwork among others.

The Reception Battalion is resourced based on the annual average rate at which new soldiers arrive for in-processing. This level of system resourcing causes recruit processing to become backlogged during surge periods where accessions peak. This creates queuing problems at various Reception Battalion stations resulting in decreased "throughput" of new recruits.

This thesis gathers and analyzes historical recruit and in-processing data for the Reception Battalion at Fort Sill, Oklahoma. The recruit reception process is modeled as a network flow problem and analyzed through the use of computer simulation. The processing system model is implemented using the Java- based *Simkit Simulation*

Software developed at the Naval Postgraduate School by Professor Arnold H. Buss (Ref. 2). It is used to compare the status quo to various policy options for improving recruit "throughput." 576 policy options are considered. These options explore the effect of various combinations of increases in manpower at the different in-processing stations on overall soldier in-processing "throughput." The effectiveness of these policy alternatives is analyzed in terms of costs and benefits against the base case, or status quo.

The results of this study indicate that a small increase in manpower at one of the in-processing stations yields a vast improvement in system throughput at savings of up to $24,000 per week. Additionally, this study illustrates previously unidentified problem areas in the structure of the current system that degrade its effectiveness during surge periods. Based on our analysis and implementation of our recommendation, the USAFATC has modified its system and reports an observable improvement of recruit "throughput" at its Reception Battalion.

I. INTRODUCTION

The United States Army recruits and trains thousands of new soldiers each year to fill vacancies in its organizations created by promotion, transfer, or termination of service. The Army trains these new soldiers at various Army Training Centers across the United States [Ref. 6:p. 10]. Though faced with the same basic mission requirements as they were ten years ago, Army Training Centers must accomplish this mission with, in some cases, half as many personnel as ten years ago. Surprisingly, the number of new soldiers trained annually has not significantly decreased during this time period. The training process is further complicated by the requirement to comply with Congressionally-mandated mixed-gender, integrated training. This requires training installations to use additional manpower and resources to ensure all standards and regulations are met such as separate and secure billeting for both male and female trainees.

The rate at which the Army brings new soldiers on active duty varies throughout the year. Accessions of new soldiers normally peak during the summer months following high school graduations. Processing centers, called Reception Battalions, receive and in-process new soldiers. Army policy mandates that all receptees process through a Reception Battalion within three workdays of arrival [Ref. 8:p. 4]. The reception process may be viewed as a network of sequential service stations that new soldiers must visit to accomplish tasks required prior to beginning basic combat training. In-processing stations include medical, dental, optical, clothing issue, and administrative paperwork among others. The Reception Battalion is resourced based on the annual average rate at which new soldiers arrive for processing. This level of system resourcing causes recruit

processing to become backlogged during surge periods when accessions peak. As a result, this creates queuing problems at various Reception Battalion stations.

The United States Army Field Artillery Training Center (USAFATC) is one of five Army Training Centers with a Reception Battalion. Given the problem described above, the Commander, USAFATC, directed a study of options to increase throughput of new soldiers through its Reception Battalion.

This thesis considers a fixed set of 576 policy options. A simulation model is used to explore the in-processing policy alternatives versus the status quo. Analysis of alternatives compares options in terms of costs and benefits. Recommended alternatives improve "throughput" at the least cost. Based on this analysis and their implementation of the recommendations in this study, USAFATC improved throughput while reducing costs, compared with the status quo.

II. BACKGROUND

The United States Army Field Artillery Training Center at Fort Sill, Oklahoma, trains nearly 15,000 Basic Combat Training (BCT) and Advanced Individual Training (AIT) soldiers each year [Ref. 9]. Soldiers who graduate from AIT will serve in various Combat Support and Combat Service Support Military Occupational Specialties (MOS). One-Station-Unit-Training (OSUT), also at Fort Sill, keeps new soldiers grouped in the same training company for both BCT and AIT. New soldiers' MOS determines the type of training they will receive and how long the training lasts. Training cycles vary from 9 to 15 weeks depending upon MOS. Soldiers report to USAFATC from various Military Entry Processing (MEP) stations throughout the United States in varying numbers ranging from 1 to 250. At Fort Sill, the 95th Adjutant General (AG) Reception Battalion processes new soldiers into the Army. Figure 1 illustrates an aggregate view of how new recruits flow from the MEP station through the initial entry training process into Army units [Ref. 6:p. 13].
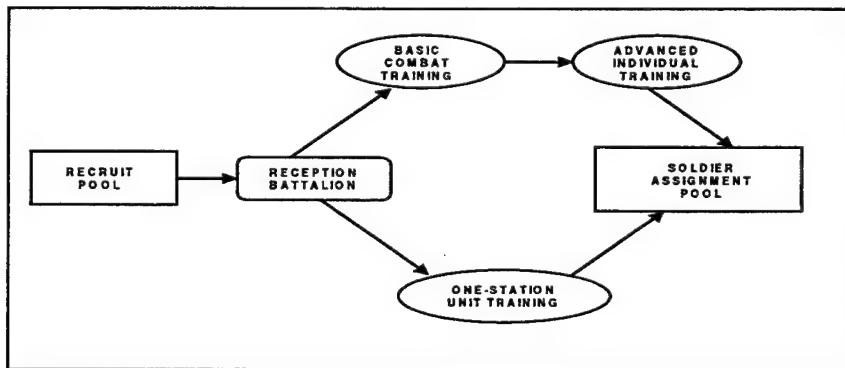
Figure 1. Aggregated View of the Initial Entry Training Process

In-processing a soldier normally takes the Reception Battalion 3 to 5 days. Once

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in-processed, soldiers are either "shipped" to basic training companies at Fort Sill or some other basic training installation, or remain at the Reception Battalion as "holdovers." Trainees may be held over for various reasons. These range from failing the physical fitness test to no openings available in basic training companies. The Reception Battalion also houses soldiers during in-processing and while they wait to start basic combat training. Problems arise when the number of new soldiers "held-over" at the Reception Battalion exceeds available billeting.

The introduction of female soldiers to basic combat training at Fort Sill compounds billeting problems. The summer training period of 1999 marks the first time in Fort Sill history that female soldiers will attend basic combat training at the USAFATC. It is estimated that 40% of all future basic combat training soldiers at Fort Sill will be female. The Reception Battalion has a fixed capacity to house soldiers. Army regulations mandate separate sleeping areas for male and female soldiers and establish minimum living space requirements. In the past, when processing male soldiers only, it was easy to fill vacant living spaces since they could be filled without consideration of gender. In the future, the requirement to house soldiers separately by gender requires the installation to designate either whole buildings or entire floors for a particular gender. This likely will preclude the Reception Battalion from efficiently filling empty living space.

The Reception Battalion processes trainees through a number of stations including medical, dental, personnel, and clothing issue (see Figure 4). Reception Battalion staffing to process new soldiers is based on the Army Table of Distribution and Allowances (TDA). This includes both active duty soldiers and government service (GS) civilian employees. At USAFATC, the Reception Battalion may augment its TDA

employees by hiring temporary or full-time civilian employees subject to budget constraints. The Reception Battalion's TDA is based on the monthly average number of recruits processed throughout the year.

Unfortunately, the Army cannot access recruits uniformly throughout the year since most new recruits are not available to enter training until they graduate from high school. Therefore, most of the recruited population arrives for in-processing during the summer months. For example, in 1998, the 95th AG Reception Battalion processed 65.2% of its new soldiers during the five summer months from May to September. This period is commonly referred to as summer surge. Summer surge causes recruit arrivals to greatly exceed the 95th's manpower capabilities to process new soldiers so they are ready to ship in three to five days. In-processing delays and trainee queue buildup often causes the 95th AG Reception Battalion to exceed its capacity to provide adequate space to house these new soldiers thus aggravating the problem.

III. PURPOSE AND RATIONALE

Over the past several years, the Army has failed to meet monthly recruiting goals during the first six months of the fiscal year. The United States Army Recruiting Command (USAREC), Fort Knox, Kentucky attempts to compensate for this shortfall by over-accessing recruits during the surge period (summer months). This requires the United States Army Training and Doctrine Command (TRADOC) at Fort Monroe, Virginia to "negotiate" with the USAFATC and other initial entry training installations on the number of additional unprogrammed recruits to send to each initial entry training installation during the surge period. This practice raises a number of questions of interest to TRADOC that motivated this thesis: Can USAFATC handle the increased training load? What will the cost in dollars, equipment, and people be to in-process the additional, unprogrammed trainees during the summer surge?

In June 1998, the U.S. Army Manpower Analysis Agency conducted a study to validate the TRADOC requirement determination process [Ref. 7:p. 10]. The study concluded that the 95th AG Reception Battalion had one-third the number of civilian authorizations it needed to properly accomplish new soldier in-processing in the three to five day time period. This study, however, did not result in changes to the 95th AG Reception Battalion's TDA. To further substantiate the conclusions of the U.S. Army Manpower Analysis Agency study, the USAFATC Commander directed an internal study to help determine what modifications were needed to best improve the current in-processing system. According to the Commander, USAFATC, a model is needed that can assist in answering TRADOC's questions as well as provide recommendations to efficiently allocate resources for more effectively processing new soldiers. This would

also help validate USAFATC's current manpower requirements and justify future TDA changes. Discussions with the USAFATC Commander identified important system performance measures that the model must be robust enough to accurately estimate. These include how long it will take to process soldiers in the future based on different soldier arrival rates and changes to the number of servers at processing stations. This information would enable USAFATC to project when to make additional temporary employees available for in-processing, when to plan for additional housing, and how much housing space to make available for "holdover" soldiers during peak periods [Ref. 11].

IV. MODEL DEVELOPMENT

A. GENERAL

A system is defined to be a collection of entities, e.g. people or machines, that logically act and interact together to accomplish some task [Ref. 4:p. 3]. A model is an abstraction or analogue of a real-world system that is usually developed to gain a better understanding of how a real-world system works. This understanding will hopefully lead to improvements in the system being modeled. The problem discussed here, studying and modeling the system for in-processing new soldiers, involves many steps where random events occur and processing times vary. The nature of the problem suggested that a stochastic simulation approach was best suited for representing and modeling the system. The model presented for studying alternatives for processing new soldiers through a Reception Battalion is a stochastic, process-oriented, event-step simulation. The model was implemented using the Java-based *Simkit Simulation Software* developed at the Naval Postgraduate School by Professor Arnold H. Buss [Ref. 2]. The stochastic aspect of the simulation model incorporates uncertain in-processing occurrences and times by drawing random observations from probability distributions [Ref. 4:p. 3]. The stochastic occurrences are characterized in terms of time to complete specific events, time between events, and the probability of whether or not a model entity, in this case a soldier, gets scheduled for a specific event. The *Simkit Simulation Software* Class, *RandomStream*, draws random values from different probability distributions for each stochastic event modeled.

The simulation model presented here uses an event-list to manage the sequence of events in the system and the time-advance mechanism. Because the Reception Battalion

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system is process-oriented, time is modeled as a continuous, rather than discrete, variable. A process-oriented model explicitly represents the passing of time allowing several system sub-process subroutines to execute simultaneously [Ref. 5:p. 17]. For example, while one soldier receives a haircut another may take a fitness test. These two events are modeled as separate processes and are conducted independently with regard to simulation time. The main benefit of a process-oriented approach is that it avoids the need to decompose the overall system and separately model distinct sub-processes either individually or sequentially [Ref. 4:p. 18].

Simkit Simulation Software was selected as the simulation software for several reasons. First, the event-scheduling methods, statistical calculation methods, and random number generation methods provided in *Simkit* are well suited to explicitly replicating the real world system under consideration [Ref. 2]. Second, since the model only produces estimates of the real world system's true characteristics for a specific set of input parameters, independent runs for each set of input parameters were required [Ref. 5:p. 115]. *Simkit* is well-suited for handling this problem, allowing multiple simulation runs for over 500 input parameter sets continuously without stopping the simulation to reset parameter values.

B. APPROACH

The study goal is to provide the decision maker, USAFATC Commander, with insights regarding how different mixes of "servers" at the various in-processing stations will affect the total time a new soldier spends in the system as well as how the proposed changes will affect total soldier throughput during a three day in-processing period. This study defines a single "server" as either personnel, or equipment, or combination of both,

required to in-process an individual soldier at an in-processing station. For example, using the simulation it is possible to assess the impact, on both processing time and on total system throughput, of simultaneously increasing one dentist at the dental station and decreasing one counselor at the counselor station. Both the dentist and the counselor represent "servers" because at each respective station, they accomplish the in-processing function. Some stations such as dental x-ray are limited to a single server due to equipment limitations, while at other stations it is possible to change the number of servers. For this study, human factors that may affect in-processing such as human error and mistakes, fatigue, apprehension, and excitement are not modeled.

In the model, we simulate service times for stations where the number of "servers" may vary as well as stations where the number of "servers" is fixed. USAFATC provided data that measured the amount of time it took a single server to process an individual soldier. From these data, probability distribution parameters were estimated for the random service times for the processing of each soldier at the various stations.

Certain stations in the system did not have to be executed by every soldier who entered the system. From data provided by the client, the proportion of soldiers required to complete these stations was determined. This was incorporated in the model as a random number drawn from a Uniform (0,1) distribution followed by an IF-THEN statement. If the random number was less than the proportion, then the soldier was required to complete that station. Otherwise, the soldier moved to the next station in the system. For example, soldiers with eyeglasses had to complete a station that validated the prescription of their eyeglasses after receiving an optical screen test, while those soldiers without eyeglasses moved directly from the optical screening test to the dental

station.

C. ASSUMPTIONS AND ESTIMATION OF PARAMETERS

Regardless of the level of detail, certain assumptions must be made when
attempting to replicate a real-world system in a computer simulation model.
Assumptions made in constructing this model are based on input from decision-makers at
the Reception Battalion, subject matter experts, and direct observations.

1. Assumptions

Significant assumptions for developing the simulation model are given below.

- Soldiers never go "off-line" once they enter the in-processing system. They
  are either waiting for the next event to begin, waiting for service in the queue
  at their current station, or are being processed at a station. Drill sergeants and
  others who supervise groups of soldiers assume this responsibility at
  USAFATC.

- The total number of servers at each station remains fixed during a
  simulation run.

- Server rest breaks only occur during idle periods when no soldiers are
  available for in-processing.

- The simulation only models operations when the system is operational
  during the three-day simulated in-processing period.

- Data provided by USAFATC is "statistically valid" and can be used to
  estimate probability distributions for modeling service and travel
  times. The effect of the variability of these estimates is minimal.

- Soldiers progressing through the simulated system move from station to station in the same order as in the real-world system except when soldiers are behind schedule due to backlogs. In reality, when the system is behind schedule, soldiers may move to stations for once-a-day type events such as briefings where the entire group can be in-processed. Drill sergeants ensure these soldiers make up missed stations at some point during the three-day period. The simulation conservatively accounts for the drill sergeant factor by keeping soldiers queued up until they complete each station.

- In the simulation, soldiers enter and leave queues on a first-in-first-out (FIFO) basis. However, in the real-world, drill sergeants may move "behind schedule" soldiers to the front of the queue when making up stations previously missed due to backlog.

2. Estimation of Parameters

Some stations process soldiers simultaneously as a group. In practice, all soldiers in the group begin processing at the same time but they do not all complete the station at the same time. In the simulation, service times for these stations were modeled differently than stations where soldiers are processed individually. Historical data provided by USAFATC for these stations, specifically clothing issue and unit photo, reflected the length of time it took to process groups of various sizes. From these data, a statistical distribution for the soldier processing rate was determined. Determining the service time for each individual soldier is done by "drawing" a random time value from the distribution described above and multiplying this value by the number of the soldiers in the group. This "weighting" procedure maintained consistency in simulating the flow

of groups of soldiers through the system. In some cases, historical data were not available for travel times between stations. These times in the simulation were modeled using either estimates from subject matter experts or direct observations of the system during site visits by the author to Fort Sill.

USAFATC provided historical data for service times at the different in-processing stations in sample sizes varying from ten to thirty data points. Though these sample sizes were relatively small, they proved suitable for this study. Histograms provide an easily interpreted visual synopsis of the data and are used for initial analysis of the data [Ref. 5:p. 361]. In queuing models, service times are most often modeled using the exponential, gamma, Weibull, lognormal, or normal distribution that best fits the data [Ref. 5:p. 326]. Curves generated from parameters of the lognormal and gamma distributions provided the best fits to observed service time histograms. The Kolmogorov-Smirnov goodness of fit test, using both the gamma and lognormal distributions, was used to determine which distribution best fit the service time data [Ref. 10]. In all cases, the gamma distribution failed to give a "good" fit to the service time data. Alternatively, the lognormal distribution proved to be a "good" fit to the service time data in all cases and was chosen to model the data. The lognormal distribution parameters, μ and σ, were determined for each case using maximum likelihood estimation. Histograms, with associated lognormal distribution curves of the data sets for service times for the Medical and Counselor stations are illustrated in Figures 2 and 3, respectively.

Lognormal Curve Fitted to Density of Medical Service Times

Medical Service Times (Hours)
n = 30 observations mean = -1.704 st. dev = .579
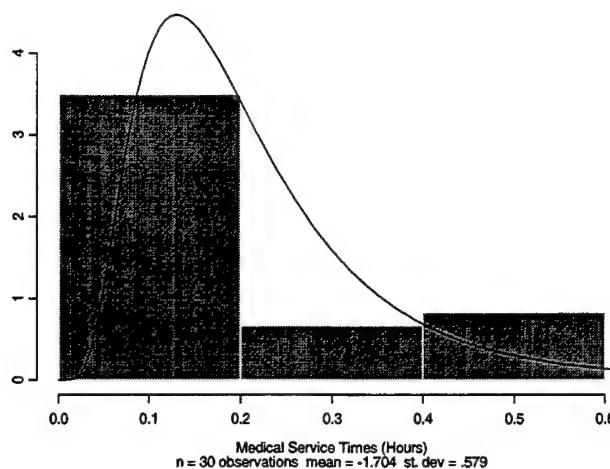
Figure 2. Medical Service Times and Associated Lognormal Distribution

Lognormal Curve Fitted to Density of Counselor Service Times

Counselor Service Times (Hours)
n = 30 observations mean = -1.2568 st. dev. = .4195
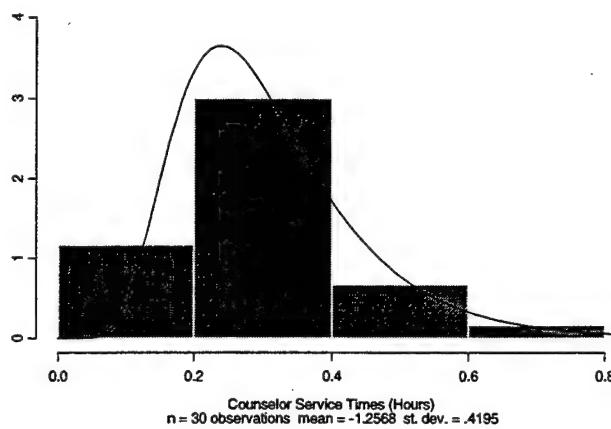
Figure 3. Counselor Service Times and Associated Lognormal Distribution

In Figures 2 and 3, the length of the curve along the x-axis depicts the range of time, in hours, from which the corresponding random service times are drawn in the simulation. The height of the curve indicates the relative frequency of random service times drawn corresponding to the x-axis values. Natural log estimated parameters for

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Medical service were $\hat{\mu} = -1.70$ and $\hat{\sigma} = 0.579$. Natural log estimated parameters for

Counselor service were $\hat{\mu} = -1.2568$ and $\hat{\sigma} = 0.4195$.

We recognize that these parameters are variable based on the small sample sizes from which they are determined. To explore the amount of uncertainty introduced into our model with regard to the small sample sizes we constructed 95% confidence intervals for the means of the observed times provided by USAFATC. First, we computed upper and lower 95% confidence limits for the parameters, μ and σ, using the following equations [Ref. 3:p. 278, 299].

$$95\% \text{ CI for } \mu = \left(\hat{\mu} - 1.96 \cdot \frac{\hat{\sigma}}{\sqrt{n}}, \hat{\mu} + 1.96 \cdot \frac{\hat{\sigma}}{\sqrt{n}} \right)$$

$$95\% \text{ CI for } \sigma = \left(\sqrt{\frac{(n-1) \cdot \hat{\sigma}^2}{\chi^2_{\frac{\alpha}{2}, n-1}}}, \sqrt{\frac{(n-1) \cdot \hat{\sigma}^2}{\chi^2_{1-\frac{\alpha}{2}, n-1}}} \right)$$

In these equations, $\hat{\mu}$ represents the estimated mean of the natural log for the observations considered, n represents the sample size, $\hat{\sigma}$ represents the estimated standard deviation of the natural log of the observations, and α represents the significance level of the confidence interval. Using the parameters for the Medical service times, we obtained 95% limits of (−1.9072, −1.4928) and (.4611, .7784) for μ and σ, respectively. Since these are the confidence limits for the natural log parameters, we next constructed 90.25% confidence limits (95% confidence limits of the 95% upper and lower bounds determined above for μ and σ) for the mean of the observed times, E[X], using the following equations [Ref. 3:p. 177].

$$E[X_L] = e^{\hat{\mu}_L + \frac{\hat{\sigma}_L^2}{2}} \qquad \qquad E[X_U] = e^{\hat{\mu}_U + \frac{\hat{\sigma}_U^2}{2}}$$

The subscripts in these equations represent the lower and upper 95% confidence limits. For the Medical service times these limits are .1651 and .3043 (hours). This indicates that based on the small sample sizes provided our service time estimates could differ from the actual service times by as much as a factor of two. Although inclusion of parameters derived from data of such small sample sizes may introduce imprecision into our model, they are better than estimates based on no historical data at all. These estimates provide us with a set of projected operating conditions that facilitate estimation of the existing system's performance through simulation [Ref. 5:p. 115]. Thus, using simulation we are still able to provide USAFATC with useful insights even though our answers are known to be inexact.

D. STRUCTURE

1. General

The in-processing system may be depicted as a linear directed node-arc network. Nodes represent each in-processing station or in-processing event. Arcs indicate the directed flow of soldiers through the system. The terms, event and station, are used interchangeably. Subsequent events are scheduled with a specified time delay. Simulated time delays between events in the model may be either stochastic or deterministic. Time delays critical to the model such as service times are represented using stochastic parameters, while delays such as movement times between stations (events) are represented deterministically based on system observations. Parameters that represent deterministic time delays remain fixed throughout the model for each set of server mixes and therefore do not affect results. Event-step models of this type lend

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themselves to graphical illustration of simulation steps called "event graphs" [Ref. 1:p. 1]. Figure 4 illustrates an event graph of soldier in-processing events.
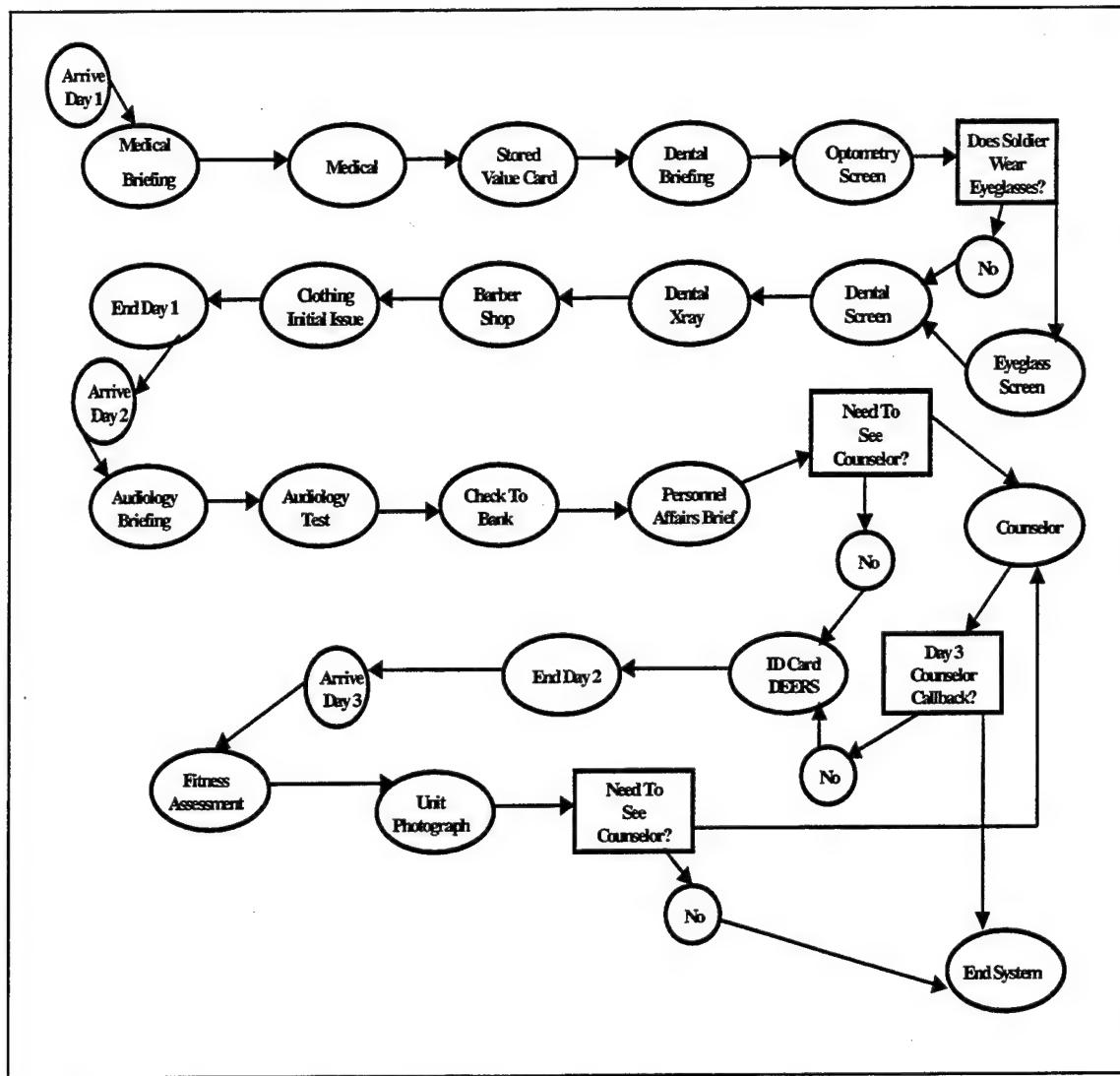
Figure 4.   Event Flow

The execution of the simulation model is accomplished in *Simkit* using a method called *Run*. *Run* initiates the arrival of soldiers at the system and sets all statistical counters and input parameters to their initial condition values. The simulation models three discrete time periods corresponding to three processing days. During each day, there are specific time windows for accomplishing in-processing tasks during that day. Time windows correspond to actual times that a server is available during the day. Total

server time available varies day by day based on stations scheduled for in-processing. Given this, the simulated length of each day also varies. For example, the total simulated processing time beginning with the opening of the first scheduled Day 1 station, Medical, to the time that the last Day 1 station, Clothing Issue, closes is 8.75 hours. Similarly, the total simulated processing time available for Day 2 and Day 3 stations is 9.5 and 5.5 hours, respectively. In the simulation, soldiers who complete all Day 1 stations in less than 8.75 hours will be delayed so that they arrive at the first Day 2 event at a simulation time of 8.75 hours. 8.75 hours defines the beginning of Day 2 in-processing activities for the first group of arrivals and the beginning of Day 1 in-processing activities for the second group of arrivals. The simulation schedules soldiers to arrive at the first Day 3 event in the same fashion. Figures 5, 6, and 7 illustrate the simulation time windows for each station, by day, for a ten day period. The first column in each figure indicates the day of the week that the soldier entered the system. The times listed under each station represent the daily time periods that those stations are open for service in simulation time (hours).

DAY 1 IN-PROCESSING								
Day 1	MEDICAL		VALUECARD		DEN/OPT/BS		CLOTH ISSUE	
Start	Open	Close	Open	Close	Open	Close	Open	Close
MON	0.00	8.75	1.50	8.75	2.50	8.75	5.50	8.75
TUES	8.75	17.50	10.25	17.50	11.25	17.50	14.25	17.50
WED	17.50	26.25	19.00	26.25	20.00	26.25	23.00	26.25
THUR	26.25	35.00	27.75	35.00	28.75	35.00	31.75	35.00
FRI	35.00	43.75	36.50	43.75	37.50	43.75	40.50	43.75
MON	43.75	52.50	45.25	52.50	46.25	52.50	49.25	52.50
TUES	52.50	61.25	54.00	61.25	55.00	61.25	58.00	61.25
WED	61.25	70.00	62.75	70.00	63.75	70.00	66.75	70.00
THUR	70.00	78.75	71.50	78.75	72.50	78.75	75.50	78.75
FRI	78.75	87.50	80.25	87.50	81.25	87.50	84.25	87.50

Figure 5. In-processing Station Simulation Time Limitations in Hours (Day 1)

DAY 2 IN-PROCESSING						
Day 2	AUDIOLOGY		CHECKBANK		PAD	
Start	Open	Close	Open	Close	Open	Close
MON	8.75	12.75	10.00	11.75	11.75	18.25
TUES	17.50	21.50	18.75	20.50	20.50	27.00
WED	26.25	30.25	27.50	29.25	29.25	35.75
THUR	35.00	39.00	36.25	38.00	38.00	44.50
FRI	43.75	47.75	45.00	46.75	46.75	53.25
MON	52.50	56.50	53.75	55.50	55.50	62.00
TUES	61.25	65.25	62.50	64.25	64.25	70.75
WED	70.00	74.00	71.25	73.00	73.00	79.50
THUR	78.75	82.75	80.00	81.75	81.75	88.25
FRI	87.50	91.50	88.75	90.50	90.50	97.00

Figure 6. In-processing Station Simulation Time Limitations in Hours (Day 2)

DAY 3 IN-PROCESSING						
Day 3	FITNESS AS		UNIT PHOTO		PAD CALLB	
Start	Open	Close	Open	Close	Open	Close
MON	18.25	19.25	19.25	21.25	21.25	23.75
TUES	27.00	28.00	28.00	30.00	30.00	32.50
WED	35.75	36.75	36.75	38.75	38.75	41.25
THUR	44.50	45.50	45.50	47.50	47.50	50.00
FRI	53.25	54.25	54.25	56.25	56.25	58.75
MON	62.00	63.00	63.00	65.00	65.00	67.50
TUES	70.75	71.75	71.75	73.75	73.75	76.25
WED	79.50	80.50	80.50	82.50	82.50	85.00
THUR	88.25	89.25	89.25	91.25	91.25	93.75
FRI	97.00	98.00	98.00	100.00	100.00	102.50

Figure 7. In-processing Station Simulation Time Limitations in Hours (Day 3)

2. Stations and Queues

The model implements events for each station listed in Figures 5, 6, and 7 above. Tasks accomplished at each station above are briefly defined below:

- Medical Processing (*Medical*). Medical processing includes three shots per soldier and drawing blood for tests. A group medical briefing precedes individual soldier in-processing.

- Stored Value Card Issue (*Value Card*). Each soldier is issued a Stored Value Card worth $200 that allows the soldier to purchase sundry items

at the local exchange.

- Dental Processing (*Den*). Each soldier receives a dental examination to identify potential dental problems. A group dental briefing precedes this station. Dental x-rays are also an event during this time period.

- Optical Examination (*Opt*). An optical screening and examination is given to each soldier. If the soldier wears eyeglasses, his prescription is also verified.

- Haircut Processing (*BS*). Each soldier receives a regulation Army haircut.

- Clothing Issue (*Cloth Issue*). Each soldier receives an initial issue of Army uniforms at the Clothing Initial Issue Point (CIIP).

- Audiology Examination (*Audiology*). Each soldier receives a hearing examination in an audiology booth that tests eight soldiers at a time. A group audiology briefing precedes this station.

- Finance Processing (*CheckBank*). Soldiers receive a briefing, fill out check-to-bank paperwork, and establish a bank account where their military pay will be directly deposited.

- Personnel Affairs Processing (*PAD*). Soldiers receive a personnel briefing, receive a military identification card (ID card), enroll in the Defense Enrollment Eligibility Reporting System (DEERS) database at the Personnel Affairs Detachment (PAD), and if necessary, consult with a personnel counselor. ID card issue and DEERS enrollment occur at the same location.

- Physical Fitness Processing (*Fitness As*). Soldiers receive a physical fitness assessment prior to entering basic combat training. This assessment determines whether the soldier is immediately assigned to the Fitness Training Battery for remedial physical fitness training or begins basic combat training upon completion of in-processing. Attrition due to fitness failure is not included in this model.

- Photo Processing (*Unit Photo*). New soldiers receive an individual photograph at this station.

- Counselor Station (*PAD CallB*). After initial in-processing at the PAD, some soldiers may consult with a counselor.

Of the 15 stations modeled, four are group stations. The four group stations are: *CIIP*, *Check to Bank*, *Fitness Assessment*, and *Unit Photo*. Group stations in-process all arrivals each day at the same time. The other eleven individual stations require at least one server to in-process each soldier. The eleven individual stations are Medical*, Stored Value Card*, Dental*, Dental X-ray, Optical Screen, Eyeglass Verification, Barber Shop*, Audiology (Hearing Test)*, PAD Briefing, ID/DEERS*, and PAD Counselor*. At the medical station, each soldier is in-processed by three medical personnel. Another special instance is the PAD brief station where seating is limited to forty. At this station each seat is considered a server.

This study considered the effects on in-processing throughput of varying the number of total servers available for the seven stations denoted above with an asterisk (*). Two outcomes occur at each station upon a soldier arrival. First, if at least one server at that station is idle, then the soldier immediately begins processing. Second, if

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all servers are busy, the soldier enters a queue and awaits a server. *Queue discipline* in the model, the rules a server follows for choosing the next customer, processes soldiers on the basis of first-in-first-out (FIFO) [Ref. 5:p. 119]. Under this rule, the soldier waiting in queue for the longest length of time is the next in line for service. Alternative queue disciplines for this simulation are not investigated. This rule allows us to conservatively estimate the total time a soldier spends in the in-processing system and does not account for drill sergeants moving "behind schedule" soldiers to the front of the queue from time to time.

3. Simulation Flow

The simulation uses three events to replicate actions at each station. These events are *Arrive*, *Start Service*, and *End Service*. Each is briefly summarized below.

- *Arrive*. This event schedules a *Start Service* event for soldiers in queue if an idle server is available. It also decrements the number of idle servers by one. If all servers are busy, then this event places the arriving soldier in queue.

- *Start Service*. Schedules an *End Service* event after a service time delay determined by a draw from a lognormal distribution.

- *End Service*. This event increments the number of available servers by one. If the station queue is not empty, a *Start Service* event is scheduled for the soldier in queue with the longest time in queue. It also schedules an *Arrive* event at the next station for the soldier that just completed service.

As discussed previously, several soldiers may in-process at one time. The simulation manages several events simultaneously and controls the timing of

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future event occurrences in the model using the *Future Event List* [Ref. 1:p. 1].

Once a future event is scheduled, it is posted to the *Future Event List*. Events are

executed from this list based on their scheduled time of occurrence. When

individual events occur instantaneously, time does not pass during event execution.

It passes based on event completion. For example, time delay is initiated in the

Start Service event when scheduling the *End Service* event. Conversely,

parameters can only change value during events such as incrementing or

decrementing the number of available servers in the *Arrive* or *End Service* events.

Since parameter values change only during event execution, the model captures

time snapshots of parameter state changes based on time of event occurrence to

change parameter values. Measures of performance for this model are determined

using the values of system parameters over certain periods of time [Ref. 1:p. 1].

E. EXAMPLE RUN

Initial conditions for this run include specifying the number of servers available at

each of the seven stations under investigation as discussed earlier. Figure 8 gives the

number of servers for this run.

Medical	Stored Value Card	Dental	Barber	Audiology	Counselor	ID/DEERS
1	1	1	2	1	5	1

Figure 8. Example Run Input Parameters

This example assumes the arrival of ten soldiers per day for two consecutive days. Using

the model implemented in *Simkit*, the user enters the parameter values shown above in

Figure 8, then presses the *return* key. This starts a method named *Run* that generates the

model. This instance method schedules the first event of the simulation. Additionally, it

initiates the arrival of soldiers and sets input parameters and statistical counters to initial

conditions. The *Run* event schedules the *Arrival* event for the twenty soldiers entering

the system. Since soldiers arrive in groups of ten for two consecutive days, the Run event

schedules ten *Arrival* events for time 0.0 (day 1) and ten *Arrival* events for time 8.75

(beginning of day 2 in simulation time). The event list displays the current event

transpiring in the simulation along with the current simulation time in hours and the times

of all of the future events scheduled by the current event. Figure 9 depicts the initial

event list upon execution of the *Run* event.

```
Time: 0.000        Current Event: Run      [1]
              ** Event List --  **
    0.000 Arrival      {Soldier@807fa82c}
    0.000 Arrival      {Soldier@8043a82c}
    0.000 Arrival      {Soldier@815ba82c}
    0.000 Arrival      {Soldier@811fa82c}
    0.000 Arrival      {Soldier@80e3a82c}
    0.000 Arrival      {Soldier@81fba82c}
    0.000 Arrival      {Soldier@81bfa82c}
    0.000 Arrival      {Soldier@8183a82c}
    0.000 Arrival      {Soldier@869ba82c}
    0.000 Arrival      {Soldier@865fa82c}
    8.750 Arrival      {Soldier@8623a82c}
    8.750 Arrival      {Soldier@8733a82c}
    8.750 Arrival      {Soldier@86f7a82c}
    8.750 Arrival      {Soldier@8413a82c}
    8.750 Arrival      {Soldier@87d7a82c}
    8.750 Arrival      {Soldier@879ba82c}
    8.750 Arrival      {Soldier@84b3a82c}
    8.750 Arrival      {Soldier@8477a82c}
    8.750 Arrival      {Soldier@843ba82c}
    8.750 Arrival      {Soldier@854fa82c}
          ** End  of Event List **
```

Figure 9. *Run* Event List (Time = 0.000)

The simulation begins with time at zero by evaluating the first event on the event

list. The *Arrival* event schedules soldiers to arrive on Day 1. The *Arrival* event then

schedules the next event, *MedArrival,* for each of the first day's soldiers, after a randomly

generated time delay. This delay simulates the time it takes to accomplish a group

medical briefing prior to medical in-processing. Obviously, since the briefing lasts the

same for all soldiers, the delay for each soldier on any day is the same. For example, the medical briefing delay for the first day group was .175 hours (see Figure 10). Figure 10 lists the event scheduled with regard to the first *Arrive* event. The alpha-numeric sequence in brackets after the current event, {Soldier@807fa82c}, depicts the *Simkit* reference to the specific soldier currently executing the *Arrive* event. The number in brackets, [1], after the soldier reference reflects the number of times the event was executed.

```
Time: 0.000        Current Event: Arrival  {Soldier@807fa82c}        [1]
                        ** Event List --   **
                   0.000 Arrival      {Soldier@8043a82c}
                   0.000 Arrival      {Soldier@815ba82c}
                   0.000 Arrival      {Soldier@811fa82c}
                   0.000 Arrival      {Soldier@80e3a82c}
                   0.000 Arrival      {Soldier@81fba82c}
                   0.000 Arrival      {Soldier@81bfa82c}
                   0.000 Arrival      {Soldier@8183a82c}
                   0.000 Arrival      {Soldier@869ba82c}
                   0.000 Arrival      {Soldier@865fa82c}
                   0.175 MedArrival   {Soldier@807fa82c}
                   8.750 Arrival      {Soldier@8623a82c}
                   8.750 Arrival      {Soldier@8733a82c}
                   8.750 Arrival      {Soldier@86f7a82c}
                   8.750 Arrival      {Soldier@8413a82c}
                   8.750 Arrival      {Soldier@87d7a82c}
                   8.750 Arrival      {Soldier@879ba82c}
                   8.750 Arrival      {Soldier@84b3a82c}
                   8.750 Arrival      {Soldier@8477a82c}
                        ** End   of Event List **
```

Figure 10. *Arrival* Event List (Time = 0.000)

The *MedArrival* event checks the parameter value representing the number of available medical in-processing servers. If greater than zero, then *MedArrival* schedules a *StartMedService* event with zero time delay for that soldier. It then decrements the number of available medical servers. If the number of medical servers available at the time of a *MedArrival* event is zero, then that soldier is placed in queue and *MedArrival* schedules no further events. The *StartMedService* event schedules an *EndMedService* event after a randomly generated time delay. The *EndMedService* schedules the soldier

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arrival at the next station; the *SvcArrival* (Stored Value Card). This station is located in the room adjacent to the medical in-processing station. Since this station is not available for in-processing until 1.5 hours (real-world time) after medical in-processing begins, the simulation adjusts for the delay using a logic sequence in the *EndMedService* event. The following Java computer code (see below) illustrates the logic used in the *EndMedService* event when scheduling *SvcArrival* based on two consecutive days of arrivals.

```
        double thisTime = Schedule.simTime();
        if (thisTime > svcOpen2) {
            waitDelay("SvcArrival", 0.0, trainee);
        }
        else if ( thisTime > ciipClose1 && thisTime < svcOpen2) {
            waitDelay("SvcArrival", (svcOpen2 - thisTime), trainee);
        }
        else if (thisTime > svcOpen1 && thisTime < ciipClose1) {
            waitDelay("SvcArrival", 0.0, trainee);
        }
        else {
            waitDelay("SvcArrival", (svcOpen1 - thisTime), trainee);
        }
```

If the *EndMedService* event simulation execution time is later than the time the Stored Value Card station normally begins service, then the *SVCArrival* event is scheduled without any time delay. However, if the *EndMedService* event execution time is earlier than the simulation time corresponding to the opening of the SVC station, then soldiers experience a delay so they arrive at the station at exactly either 1.5 or 10.25 hours into the simulation. This is how the system works in practice with soldiers lined up at the SVC station waiting for the station operator to begin service. After scheduling the *SvcArrival*, the *EndMedService* event increments the value of the number of available servers and checks for soldiers in the medical queue. If the medical queue is not empty, the *EndMedService* schedules a *StartMedService* event for the soldier at the top of the queue and decrements the number of available medical servers. This process repeats until no soldiers remain in the medical queue.

The *SvcArrival* event schedules the *StartSvcService* event according to the rules for the *MedArrival* event discussed above. The *StartSvcService* event schedules an *EndSvcService* event after a random time delay. Similar to the *EndMedService* event, the *EndSvcService* event schedules a *DOArrival* (Dental-Optical briefing) event depending on current simulation time. The building where the Dental-Optical briefing takes place is not available for in-processing until 2.5 hours into the day's events. This operating procedure is incorporated into the *EndSvcService* event for scheduling *DOArrival*. *DOArrival* schedules the *DOBrief* with no time delay. Since several *DOArrival* events may be scheduled for the same time, the event list schedules the *DOBrief* for the exact same time but places it on the event list after all previously scheduled events scheduled at the same time in the simulation. Figure 11 illustrates the process and event schedule.

```
Time: 2.500        Current Event: DOArrival      {Soldier@807fa82c} [1]
                         ** Event List --   **
                   2.500 DOArrival   {Soldier@8043a82c}
                   2.500 DOArrival   ·{Soldier@815ba82c}
                   2.500 DOArrival   {Soldier@811fa82c}
                   2.500 DOArrival   {Soldier@80e3a82c}
                   2.500 DOArrival   {Soldier@81fba82c}
                   2.500 DOArrival   {Soldier@81bfa82c}
                   2.500 DOArrival   {Soldier@8183a82c}
                   2.500 DOArrival   {Soldier@869ba82c}
                   2.500 DOArrival   {Soldier@865fa82c}
                   2.500 DOBrief     {Soldier@807fa82c}
                   8.750 Arrival     {Soldier@8623a82c}
                   8.750 Arrival     {Soldier@8733a82c}
                   8.750 Arrival     {Soldier@86f7a82c}
                   8.750 Arrival     {Soldier@8413a82c}
                   8.750 Arrival     {Soldier@87d7a82c}
                   8.750 Arrival     {Soldier@879ba82c}
                   8.750 Arrival     {Soldier@84b3a82c}
                   8.750 Arrival     {Soldier@8477a82c}
                   8.750 Arrival     {Soldier@843ba82c}
                   8.750 Arrival     {Soldier@854fa82c}
                        ** End  of Event List **
```

Figure 11. *DOArrival* Event List (Time = 2.500)

The *DOBrief* schedules the *OPTArrival* event which, in turn, schedules the *OscreenArrival* (optical screen station) event. Time delays between these three events

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are imposed each day using the same procedure discussed above for group events. Group time delays account for the dental-optical briefing time as well as time to move the group to the dental and optical in-processing location.

OscreenArrival checks for the number of personnel operating the optical screen station. If greater than zero, then *OscreenArrival* schedules a *StartOService* event and decrements the number of available optical screen personnel. If all optical screen station personnel are busy, then *OScreenArrival* places that soldier in the optical queue. *StartOService* schedules an *EndOService* event after a service time delay. Similar to *EndService* station procedures discussed earlier, *EndOService* decrements the number of available optical screen personnel and then, if the optical queue is not empty, schedules (without delay) a *StartOService* event for the next soldier in queue. *EndOService* checks whether the soldier who just completed screening wears eyeglasses using a Uniform (0,1) random draw based on historical data provided by USAFATC. If the soldier wears glasses, *EndOScreen* schedules the *ArriveEyeGlass* event with no travel delay since eyeglass verification station is located next to the optical screening station. Otherwise, it schedules the *ArriveDentService* event. Java computer code used in scheduling these events is given below.

```
double eyes = optical.uniform(0,1);
if ( eyes < eyeProb) {
   waitDelay("ArriveDentScreen",
   optMove.logNormal(oMoveMean, oMoveStd), trainee);
}
else {
   waitDelay("ArriveEyeGlass", 0.0, trainee);
}
```

The *ArriveEyeGlass* event operates the same as the *Arrival* event discussed previously. The *StartEyeGlassService* event is followed by the *EndEyeGlassService*

event which automatically schedules the *ArriveDentService* event after a time delay.

Dental, X-ray, and Barber stations are simulated similar to previous stations. The

EndBarberService event schedules the next event: Clothing Initial Issue (*CIIPArrival*).

The Clothing Initial Issue Point (CIIP) in the actual system is not open for in-processing

until approximately 5.5 hours after the first group of soldiers arrive for in-processing for

the day. The time to complete CIIP is modeled as a function of the number of soldiers in

the group arriving at the station. This information is used later when computing the time

delay between the *StartCIIPService* and *EndCIIPService* events. The following Java

computer code illustrates the logic used in scheduling these *CIIPArrivals* as well as

determination of the number of soldiers arriving at the station in groups based on two

consecutive days of arrivals.

```
    double thisTime = Schedule.simTime();
    if (thisTime > ciipOpen2) {
        waitDelay("CIIPArrival", 0.0, trainee);
    }
    else if ( thisTime > ciipClose1 && thisTime < ciipOpen2) {
        waitDelay("CIIPArrival", (ciipOpen2 - thisTime), trainee);
        CIIP2++;
    }
    else if (thisTime > ciipOpen1 && thisTime < ciipClose1) {
        waitDelay("CIIPArrival", 0.0, trainee);
    }
    else {
        waitDelay("CIIPArrival", (ciipOpen1 - thisTime), trainee);
        CIIP1++;
    }
```

CIIPArrival schedules a *StartCIIPService* event with no time delay. Unlike other

stations, the *CIIP* station in-processes all soldiers at the same time. *StartCIIPService*

schedules *EndCIIPService* after a random time delay based on the soldier processing rate

at the *CIIP* station. The simulation computes delay time for each soldier by multiplying

the random number by the total number of soldiers in the group. The following Java

code illustrates the logic for modeling two consecutive days of soldier arrivals at the *CIIP*

station.

```
public void doStartCIIPService(Soldier trainee) {
   double thisTime = Schedule.simTime();
   if(thisTime > ciipOpen2) {
      waitDelay("EndCIIPService", random1.logNormal(ciipMean,
         ciipStd), trainee);
   }
   else if (thisTime == ciipOpen2) {
      waitDelay("EndCIIPService", CIIP2*(random1.logNormal(
         ciipMean, ciipStd)), trainee);
   }
   else if(thisTime > ciipOpen1) {
      waitDelay("EndCIIPService", random1.logNormal(ciipMean,
         ciipStd), trainee);
   }
   else {
      waitDelay("EndCIIPService", CIIP1*(random1.logNormal(
         ciipMean, ciipStd)), trainee);
   }
```

EndCIIPService schedules the audiology briefing (*ArriveAudBrief*) which is the

first event of the second day. Day 2 in-processing for the first group of arrivals does not

begin before 8.75 hours in simulation time. Figure 12 illustrates the event-list generated

following the final *EndCIIPService* event.

```
Time: 5.805          Current Event: EndCIIPService {Soldier@815ba82c}[10]
                         ** Event List --   **
             8.750     Arrival              {Soldier@8623a82c}
             8.750     Arrival              {Soldier@8733a82c}
             8.750     Arrival              {Soldier@86f7a82c}
             8.750     Arrival              {Soldier@8413a82c}
             8.750     Arrival              {Soldier@87d7a82c}
             8.750     Arrival              {Soldier@879ba82c}
             8.750     Arrival              {Soldier@84b3a82c}
             8.750     Arrival              {Soldier@8477a82c}
             8.750     Arrival              {Soldier@843ba82c}
             8.750     Arrival              {Soldier@854fa82c}
             8.750     ArriveAudBrief       {Soldier@81fba82c}
             8.750     ArriveAudBrief       {Soldier@81bfa82c}
             8.750     ArriveAudBrief       {Soldier@869ba82c}
             8.750     ArriveAudBrief       {Soldier@811fa82c}
             8.750     ArriveAudBrief       {Soldier@80e3a82c}
             8.750     ArriveAudBrief       {Soldier@8043a82c}
             8.750     ArriveAudBrief       {Soldier@8183a82c}
             8.750     ArriveAudBrief       {Soldier@807fa82c}
             8.750     ArriveAudBrief       {Soldier@865fa82c}
             8.750     ArriveAudBrief       {Soldier@815ba82c}
                    ** End  of Event List --   **
```

Figure 12. *EndCIIPService* Event List (Time = 5.805)

The time an individual soldier completes in-processing at the *CIIP* station

determines the delay between *EndCIIPService* and *ArriveAudBrief.* The delay is simply

the difference between the current simulation time and 8.75 for Day 1 arrivals, or the Day

2 start time for subsequent arrivals. During actual in-processing, soldiers complete *CIIP*

in-processing the same day it starts. Therefore, the *CIIP* station does not close until all

soldiers that started finish. In the simulation, soldiers whose *EndCIIPService* occurs at a

simulation time greater than 8.75 hours are scheduled for *ArriveAudBrief* with zero time

delay. This accurately models the flow of soldiers in the system as well as provides an

accurate portrayal of the actual amount of time it takes each soldier to in-process.

ArriveAudBrief schedules *AudArrival* after a time delay. Day 1 soldiers whose

EndCIIPService event occurred after 8.75 simulation hours are subjected to the same

time delay as the rest of the group which reflects the amount of time each soldier actually

spends in the system. The audiology station consists of a computer operator and one

audiology testing system with eight individual hearing booths. If the number of booths available is greater than zero, then *AudArrival* schedules a *StartAudService* event and decrements the number of open booths. If all booths are busy, the current arrival is placed in the audiology queue. The *StartAudService* schedules an *EndAudService* event after a service time delay. *EndAudService* increments the number of booths available. If a soldier is present for in-processing, the *StartAudService* event begins without delay and decrements available booths. Finally, *EndAudService* schedules a *CheckArrival* event for the soldier that just completed the audiology test.

The Check to Bank station is only open for a certain length of time each day. Therefore, during in-processing, all soldiers arrive at the Check to Bank station at the same time. If they have not completed audiology before going to Check to Bank, then they return to audiology after completing Check to Bank. However, in the simulation soldiers remain at the audiology station until complete. This difference between actual in-processing and the simulation is accounted for in the total time a soldier spends in the system. For example, a soldier whose total system time was greater than 23.75 hours (actual system time) indicates a system blockage or lag. Events such as CheckArrival (occurring after 10.0 hours) deviating from the actual time windows are able to be identified from the event-list. *EndAudService* cannot schedule *CheckArrival* prior to simulation time of 10.0 hours for soldiers who begin in-processing at simulation time zero. *CheckArrival* schedules *PadArrival* after a randomly generated group delay for each day. The simulation uses the time delay for soldiers whose *EndAudService* event occurred after 10.0 hours.

The Personnel Affairs Division (PAD) briefing room is limited to 40 seats. *PadArrival* schedules *a StartPadBriefing* immediately if empty seats are available. If all 40 seats are filled, *PadArrival* places the next arrival into queue. *StartPadBriefing* schedules *EndPadBriefing* after a briefing time delay for all soldiers attending the briefing. *EndPadBriefing* generates a uniform (0,1) random number to determine which soldiers who completed the briefing need to see a personnel counselor. If the number is less than .6 (determined from historical data provided by USAFATC), it schedules the *ArriveIDDeers* event otherwise it schedules *ArrivePadCounselor*. The following Java code illustrates the logic used for this event scheduling.

```
double paperProblem = paperwork.uniform(0,1);
      if ( paperProblem < paperProb) {
          waitDelay("ArriveIDDeers", 0.0, trainee);
      }
      else {
          waitDelay("ArrivePadCounselor", 0.0,
trainee);
      }
```

The simulation manages *ArrivePadCounselor* in the same manner as many previous stations. It checks the number of available counselors. If the number of available counselors is greater than zero, a *StartCounselorService* is immediately scheduled, otherwise the soldier is placed in the counselor queue. *StartCounselorService* schedules *EndCounselorService* after a random time delay. *EndCounselorService* executes the same events as other end service events. It also schedules an *ArriveIDDeers* event for the soldier whose counselor service just ended.

The IDDeers station is the last in-processing station for the second day of processing. The simulation handles it in the exact same manner as the Counselor station. The *EndIDDeers* event schedules the *FitArrival* event, the first event of the third day of in-processing. The simulation determines the time delay between these two events so

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that the first *FitArrival* event is scheduled no sooner than 18.25 hours in simulation time. The *EndIDDeers* event includes a counter that collects the number of "on-time" (soldiers who complete the all of the events in the first two days in less than 18.25 hours of simulation time) soldiers who are scheduled for the *FitArrival* event at exactly 18.25 hours in simulation time.

FitArrival schedules *StartFit* without delay. *StartFit* schedules *EndFit* after a time delay that is a random number based on the rate at which the fitness assessment station can process one soldier. Using the same methodology as the *StartCIIPService* event, the simulation computes the delay time for each individual soldier by multiplying this random number by the total number of soldiers that arrived at the station together. If a soldier arrives at this station individually, then the delay between *StartFit* and *EndFit* is the random number representing the rate. The basis for this methodology draws from data provided by the client and personal observations of the author. *EndFit* schedules *ArriveUnitPhoto* no sooner than a simulation time of 19.25 which reflects the time that the Unit Photo station is available in the actual system. The simulation computes the unit photo station time delays in the same manner as it did for the CIIP and fitness assessment stations.

The *EndPhoto* event schedules either an *ArriveCallBack* event or an *EndSystem* event. A uniform (0,1) random variable based on historical data provided by the client determines which event it schedules for each soldier. If the random number is greater than .2, it schedules *EndSystem*. At this time the soldier has completed all in-processing stations and is no longer in the system. The simulation records the total time the soldier spent in the system for later use. If the random number is less than .2, the soldier must return to the counselor station for additional personnel related in-processing. Figure 13

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illustrates an event list generated during an *EndPhoto* event that has both *EndSystem* and

ArriveCallBack (boldface) events scheduled.

```
Time: 19.536        Current Event: EndPhoto        {Soldier@80e3a82c} [7]
                         ** Event List --    **
            19.536      EndSystem          {Soldier@80e3a82c}
            19.555      EndPhoto           {Soldier@869ba82c}
            19.560      EndPhoto           {Soldier@81bfa82c}
            19.570      EndPhoto           {Soldier@8183a82c}
            19.780      ArriveCallBack     {Soldier@8043a82c}
            20.227      EndPadBriefing     {Soldier@8477a82c}
            20.227      EndPadBriefing     {Soldier@8623a82c}
            20.227      EndPadBriefing     {Soldier@854fa82c}
            20.227      EndPadBriefing     {Soldier@84b3a82c}
            20.227      EndPadBriefing     {Soldier@8413a82c}
            20.227      EndPadBriefing     {Soldier@87d7a82c}
            20.227      EndPadBriefing     {Soldier@86f7a82c}
            20.227      EndPadBriefing     {Soldier@843ba82c}
            20.227      EndPadBriefing     {Soldier@8733a82c}
            20.227      EndPadBriefing     {Soldier@879ba82c}
                   ** End  of Event List --   **
```

Figure 13. *EndPhoto* Event List (Time = 19.536)

ArriveCallBack functions the same as the *ArrivePadCounselor* event. If the number of available counselors is greater than zero, *ArriveCallBack* decrements the number of available "call-back" counselors and schedules *StartCBService* without delay. Otherwise, it places the soldier into the "call-back" counselor queue. *StartCBService* schedules *EndCBService* after a random time delay. *EndCBService* increments the number of available counselors and schedules *StartCBService* if the "call-back" queue is not empty. Additionally, it schedules *EndSystem* for the soldier that just completed the counselor service. Once *EndSystem* is executed for every soldier that entered the system, the simulation run terminates. Figure 14 illustrates the event list for the last scheduled event in the example run. Since the example run demonstrates the flow of twenty soldiers through the system, the figure accurately reflects that this is the twentieth execution of the *EndSystem* event.

```
Time: 28.902        Current Event: EndSystem        {Soldier@854fa82c} [20]
                           ** Event List --    **
                                << empty >>
                        ** End   of Event List --   **
```

Figure 14. *EndSystem* Event List (Time = 28.902)

V. ANALYSIS OF POLICY OPTIONS

A. PURPOSE AND PROBLEM REVISITED

As previously discussed, this thesis explores the policy options available to the USAFATC to increase throughput at its Reception Battalion in the most efficient and cost effective manner. Using a simple event-step simulation, reasonable options are considered. Specifically, this study considers the effect that changing the balance of available manpower at the in-processing stations in the Reception Battalion has on increasing its daily throughput. This study considers 576 policy options. These consist of increases in hardware and manpower at the seven in-processing stations that the USAFATC is able to change. Some of the hardware and manpower considered is currently available but not used due to other constraints. To some degree, this study quantifies the effect of reprogramming these assets into the in-processing stations by estimating the increased soldier throughput.

The server structure illustrated in Figure 8 (page 24) and used in the Example Run discussed in the previous chapter provides the base case policy option. This is the structure currently utilized by the USAFATC during the non-surge period. From this baseline, this study modifies the server structure at the seven in-processing stations within the USAFATC's purview to change. We explore each change to the base case using simulation. The USAFATC specified the range of numbers of servers at each of the seven in-processing stations to consider. They are:

- Medical: one or two teams of three servers.

- Stored Value Card: one, two, or three servers.

- Dental: one or two dentists.

- Barber: two or three servers.

- Audiology: one machine with eight booths or two machines with eight booths.

- ID Card/DEERS: one, two, or three servers to operate the three machines available.

- Counselors: five, six, seven, or eight counselors.

576 policy options result when exhausting all possible combinations of the above servers.

B. DESIGN OF EXPERIMENT

This study explores the 576 policy options through simulation. The results for each option are grouped according to the total increase in servers from the baseline structure. They are then ranked in terms of total "on-time" throughput and also by savings from the cost associated with soldiers remaining in the system for longer than three days under the baseline structure. Total "on-time" throughput is the number of soldiers that completed the system in 23.75 hours or less, the simulation equivalent of the three allocated in-processing days. The USAFATC considers cost as the sum of the salary for a temporary hire employee per week ($500 per week) and the cost associated with a soldier remaining at the Reception Battalion for more than the three prescribed days ($17.50 per soldier per day).

The simulation modeled each option based on the arrival of 1,000 soldiers for a single week. Based on historical data, 1,000 arrivals is the largest number of arrivals the USAFATC can expect for any given week during the "surge" period. The simulation determines what proportion of the 1,000 arrivals occurs on each day (Monday through Friday) based on arrival data collected during the 1998 "summer-surge" period.

After validating the simulation model (discussed in Section C of this chapter), a simulation "run" for each option was completed. A simulation "run" consists of 40 replications of 1,000 weekly arrivals for each policy option. To determine the number of replications for each simulation "run," an absolute precision algorithm was used. The author selected twenty-five policy options ranging from the base case to the maximum option with an increase of eleven servers and ran the simulation. The absolute precision algorithm computed the average time an individual soldier spent in the system for each replication, and then recomputed the average time based on all previous replications. It terminated the simulation "run" when the average system time from all of the previous replications indicated with 95% confidence to be within 10 minutes of the true average system time [Ref. 5:p. 537]. The number of replications required for each of the twenty-five selected options ranged between 30 and 40. The author selected the largest number of replications, 40, from the absolute precision "runs" to use in the actual simulation "runs."

C. MODEL VERIFICATION AND VALIDATION

One of the most difficult problems facing a simulation analyst is to determine whether a simulation model is an accurate representation of the actual system being studied [Ref. 5:p. 298]. Through verification and validation (V&V) a modeler can ensure that a model built to replicate a given system is accurate. In other words, the model does what it is designed to do and generates reasonable results. Positive verification determines that the simulation performs as intended. This involves mathematical and logical verification of simulation parameters as well as debugging the computer program. Once accomplished, verification ensures that the conceptual simulation in the form of

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flowcharts and assumptions is correctly translated into a working computer simulation [Ref. 5:p. 299]. Validation determines whether the conceptual model now in the form of a simulation accurately replicates the system under consideration. Validation of a model involves three categories of validity: internal validity, external validity, and face validity. Internal validity is similar to verification in that it considers if the model is scientifically, logically, and mathematically sound. External validity is the comparison of model output with actual real-world system output. Face validity considers the opinion of an experienced system subject matter expert as to whether the model provides credible results.

Verification and validation is a difficult process that takes a great deal of time. Most topical references argue that while a complete V&V is extremely important, it is often too expensive and time-consuming [Ref. 5:p. 301]. In the context of this study, verification of the simulation model is not extremely difficult; however, providing proper external validation to the model would prove to be extremely time consuming and require vast effort. This would require the client to modify his existing system and collect detailed data while continuing with day to day operation of the in-processing system, a burden that the client is unwilling to undertake.

Since proper external validation of this model did not occur, V&V for this model relies on proper verification as well as both internal and face validity. Mathematical and logical verification of this model were ongoing throughout its development and were continuously assessed and evaluated by the author and advisors. Additionally, the internal validation of the model was considered along those same lines. Finally, the client approved of the conceptual framework of the model as well as the results it generated, thus lending face validation to this study. The client adopted some of the

recommended changes to the in-processing system based on the results of this study. The client reports that the recommended changes have successfully increased the in-processing system throughput. However, due to personnel limitations, the client could not capture data to determine if the actual throughput increase was similar to the increase predicted by the model. Nevertheless, this face validation of the model by the client adds credibility to the model developed during this study.

D. RESULTS

1. General

The simulation captured several different statistics for each policy option. These statistics included the mean number of soldiers in queue for each of the seven servers, the amount of time that the servers at the in-processing stations were utilized, and the average amount of time a soldier spent in each of the server queues. Additionally, the simulation captured the total on-time throughput for each of the three in-processing days as well as the average time that it took an individual soldier to complete the system. The simulation also captured the number of soldiers that failed to complete the system on time, and the length of their delay.

Although the client's primary interest in this study was total on-time throughput and associated cost, these additional statistics provide information that can assist the client in determining where blocks or backlogs occur in the system. With this information, the client can change the order of the stations in the system to alleviate blockages and ensure a more constant rate of soldier flow throughout the entire system. For example, several of the policy options yielded an "on-time" throughput for the three day in-processing period of over 800 soldiers out of the possible 1,000. However, these

same options yielded an "on-time" throughput for the first in-processing day of a little more than 200. This is a strong indicator that, while the total time allocated to in-processing during the three day period is acceptable, it is not utilized properly. Some of the in-processing stations scheduled for the first day should be moved to the second or third day to reduce blocks in the system and ensure a smoother flow of soldiers.

2. Method

One simulation run of 40 iterations was completed for each possible policy option for a total of 576 runs. It took approximately 15 minutes for each run. Using five personal computers with Intel Pentium II processors operating at 220MHz, all runs were completed in approximately 26 hours.

3. Output

Figure 15 displays the output reflecting the top 32 policy options after the completion of all simulation runs. This figure orders the top three options for each increase in the number of overall servers from the base case option in terms of total "on-time" throughput and savings (End system on Time and Savings/Week columns respectively). Columns "M" through "ID" refer to servers at the in-processing stations as follow:

- M: Medical in-processing teams at the medical station.

- SV: Stored Value Card servers.

- D: Dentists.

- B: Barbers.

- A: Audiology stations consisting of eight booths per station.

- C: Counselors.

- ID: ID Card/DEERS servers operating the ID/DEERS computer system.

Servers								System Time (hours)	End System on time	Addtl. Cost Per Week	Savings Per Week	End Day 1 on time	End Day 2 on time	Extra Day required	Extra 2 Days required	Extra 3 Days required
Increase	M	SV	D	B	A	C	ID									
0	1	1	1	2	1	5	1	34.4	262.9	$ 27,860	$ -	202.3	184.5	210.5	198.3	328.3
1	1	1	1	2	1	5	2	21.8	813.2	$ 3,770	$ 24,090	202.3	484.8	186.8	0.1	0.0
1	1	1	1	2	1	6	1	34.3	263.7	$ 28,343	$ (483)	202.3	184.5	210.1	197.9	328.4
1	1	1	1	3	1	5	1	34.4	262.9	$ 28,360	$ (500)	202.3	184.5	210.5	198.3	328.3
2	1	1	1	2	1	6	2	21.7	830.6	$ 3,966	$ 23,895	202.3	489.4	169.4	0.1	0.0
2	1	1	2	2	1	5	2	21.8	815.2	$ 4,234	$ 23,626	203.6	486.2	184.8	0.0	0.0
2	1	1	1	3	1	5	2	21.8	813.2	$ 4,270	$ 23,590	202.3	484.8	186.8	0.1	0.0
3	1	1	1	2	1	7	2	21.7	838.0	$ 4,336	$ 23,524	202.3	489.8	162.0	0.0	0.0
3	1	1	2	2	1	6	2	21.7	832.5	$ 4,432	$ 23,429	203.5	490.7	167.5	0.0	0.0
3	1	1	1	3	1	6	2	21.7	830.6	$ 4,466	$ 23,395	202.3	489.4	169.4	0.1	0.0
4	1	1	1	2	1	8	2	21.6	839.7	$ 4,807	$ 23,054	202.3	490.0	160.3	0.1	0.0
4	1	1	2	2	1	7	2	21.7	839.4	$ 4,812	$ 23,049	203.6	490.8	160.5	0.1	0.0
4	1	1	1	3	1	7	2	21.7	838.0	$ 4,836	$ 23,024	202.3	489.8	162.0	0.0	0.0
5	1	1	2	2	1	8	2	21.6	841.8	$ 5,270	$ 22,591	203.7	491.3	158.2	0.0	0.0
5	1	1	1	3	1	8	2	21.6	839.7	$ 5,307	$ 22,554	202.3	490.0	160.3	0.1	0.0
5	1	2	1	2	1	8	2	21.6	839.7	$ 5,307	$ 22,554	202.3	490.0	160.3	0.1	0.0
6	1	1	2	3	1	8	2	21.6	841.8	$ 5,770	$ 22,091	203.7	491.3	158.2	0.0	0.0
6	1	2	2	2	1	8	2	21.6	841.8	$ 5,770	$ 22,091	203.7	491.3	158.2	0.0	0.0
6	2	1	2	2	1	8	2	21.6	841.7	$ 5,771	$ 22,090	203.7	491.3	158.3	0.0	0.0
7	1	2	2	3	1	8	2	21.6	841.8	$ 6,270	$ 21,591	203.7	491.3	158.2	0.0	0.0
7	1	3	2	2	1	8	2	21.6	841.8	$ 6,270	$ 21,591	203.7	491.3	158.2	0.0	0.0
7	2	1	2	3	1	8	2	21.6	841.8	$ 6,270	$ 21,591	203.7	491.3	158.2	0.0	0.0
8	1	3	2	3	1	8	2	21.6	841.8	$ 6,770	$ 21,091	203.7	491.3	158.2	0.0	0.0
8	2	2	2	3	1	8	2	21.6	841.8	$ 6,770	$ 21,091	203.7	491.3	158.2	0.0	0.0
8	2	3	2	2	1	8	2	21.6	841.8	$ 6,770	$ 21,091	203.7	491.3	158.2	0.0	0.0
9	2	3	2	3	1	8	2	21.6	841.8	$ 7,270	$ 20,591	203.7	491.3	158.2	0.0	0.0
9	1	3	2	3	2	8	2	21.6	841.3	$ 7,279	$ 20,582	203.6	490.6	158.7	0.0	0.0
9	2	2	2	3	2	8	2	21.6	841.3	$ 7,279	$ 20,582	203.6	490.6	158.7	0.0	0.0
10	2	3	2	3	2	8	2	21.6	841.3	$ 7,779	$ 20,082	203.6	490.6	158.7	0.0	0.0
10	2	3	2	3	1	8	3	21.9	839.3	$ 7,813	$ 20,048	203.6	562.8	160.7	0.0	0.0
10	1	3	2	3	2	8	3	21.9	837.9	$ 7,838	$ 20,023	203.6	561.2	162.1	0.0	0.0
11	2	3	2	3	2	8	3	21.9	837.7	$ 8,341	$ 19,520	203.6	561.2	162.3	0.0	0.0

Figure 15. Simulation Output Reflecting Top 32 Policy Options

The numbers in bold under these columns indicate where the number of servers for a specific in-processing station have increased from the baseline.

This output provides a great deal of insight into problem areas in the system as well as potential improvements. With the increase of three additional servers the system can increase its "on-time" throughput by 575 soldiers for a given week. An increase of more than three servers yields negligible improvement to system throughput and results in greater costs. Additionally, the increase of one ID Card server reduces the average time for a soldier to complete the system by approximately 12.5 hours as well as increases the "on-time" throughput for the second day by 300 soldiers. From this information one can also assume that having only one ID Card server causes a bottleneck in the system.

This output also illustrates trends in the system structure caused by the scheduling of too many in-processing stations on certain days. The "Day 1 on-time" throughput, which is always near 200 soldiers, indicates the scheduling of too many in-processing stations for accomplishment on the first day. From event-step analysis of our simulation model a system block occurs due to the single X-ray machine which slows the flow of in-processing soldiers. The X-ray station is limited to one X-ray machine based on equipment availability and was not considered as a varying server station. Additionally, the "Day 1 on-time" numbers illustrated in Figure 15 depict the number of soldiers that completed all Day 1 in-processing stations in 8.75 hours or less. In the real-world system these numbers are slightly higher based on the previously stated policy that the CIIP station does not close until all soldiers that started finish. In actuality these numbers would be near 250 which is still a low "on-time" throughput for the first day. These insights combined with the "on-time" throughput of over 800 soldiers in three days illustrates that there are slack times associated with the second and third in-processing days that allow the soldiers who did not complete the first or second day "on-time" to catch up and complete the total system "on-time."

These results would cause one to wonder why the system as it stands has remained in place and not been the subject of previous analysis. There are several reasons. First of all, the decision-makers associated with the actual Reception Battalion in-processing system are only in place for a maximum of two years, and thus may only experience the surge period twice. Once involved in the surge period, there is no time to step back and analyze; they must continue to make the current system work. Second, for the remaining nine months of the year the baseline server structure consistently works for them as they receive a maximum of only 300 soldiers per week. Therefore, it is easy to

return to business as usual once the status quo of incoming soldiers returns and forget the problems associated with the "summer surge" period. To illustrate this point the simulation was run for the status quo server structure for weekly arrivals of 300, 400, and 500 soldiers. Only when the simulated system received 500 inputs did it fail to in-process all arrivals "on-time." Figure 16 illustrates these results.

Servers							System Time	End System	End Day 1	End Day 2	Extra Day	Extra 2 Days	Extra 3 Days	Soldiers
M	SV	D	B	A	C	ID	(hours)	on time	on time	on time	required	required	required	per Week
1	1	1	2	8	5	1	19.84	300.0	298.8	300.0	0.0	0	0	300
1	1	1	2	8	5	1	19.987	400.0	383.0	379.5	0.0	0	0	400
1	1	1	2	8	5	1	20.229	496.2	419.7	329.7	3.8	0	0	500

Figure 16. Status Quo Server Structure For Non-Surge Arrivals

With the current system in place the least cost and most beneficial option for the USAFATC to pursue would be to add one additional server to the ID Card station. This would save them approximately $24,090 for a week with 1,000 arrivals and would result in approximately 81.3% "on-time" throughput. Additional increases in manpower would result in an increased throughput of approximately 26 soldiers per week (84%), but at an increased cost of over $1,000 for a week with 1,000 arrivals. Thus, by simply adding one additional server to a specific station (ID station), the USAFATC can dramatically increase its "on-time" throughput at the Reception Battalion at a much lesser cost. The results of this study also reveal that without modifying the structure of the current system, backlogs will remain. This information leads to recommendations on how to improve the current in-processing system should the USAFATC desire.

4. Recommended Changes To The Current System

There are numerous modifications to the current system for further exploration. After conducting tedious event-step analysis of the simulation replicating the current system, it is quite clear that the Reception Battalion schedules too many stations on the

first in-processing day when faced with the task of processing the large groups of soldiers during surge periods. This backlog created during the first day creates a ripple effect through the remaining two days.

The Reception Battalion schedules all of these first day stations on the first day for good reason. The scheduling of Medical, Dental and Optical examinations up front provides time during the next two days for follow-up hospital appointments if soldier health problems are identified early. The Stored Value Card is important, because it provides the soldier with money to purchase sundry items for personal use. Additionally, the Barber station ensures that new soldiers conform to military regulations regarding personal appearance. Finally, the CIIP station provides soldiers with their Army uniforms.

In an attempt to illustrate possible improvements to the structure of the current system, the author chose to simulate an alternative with minimal impact on the current system. Review of the output previously illustrated as well as executing the simulation in event-step mode results in the following recommendations:

- Move the Clothing Initial Issue Point station to the afternoon of the third day. This results in soldiers wearing physical training uniforms during the three days of in-processing. Since the surge period is in the summer, this would also probably be a more comfortable uniform for the soldiers.

- Assign two counselors to work during the evenings and handle all call-back counseling during the evenings of the second and third day of in-processing.

- There is unscheduled slack time on the third day used to allow "behind schedule" soldiers to make up missed stations. This slack time corresponds with the time that the CIIP station is available to the USAFATC. Since the third day

only schedules in-processing during a 5.5 hour period of time, increase the in-processing time by three hours to 8.5 hours.

These changes are merely an ad hoc recommendation and would have minimal impact on the current system as it exists. Figure 17 illustrates the system with these recommended changes in place.
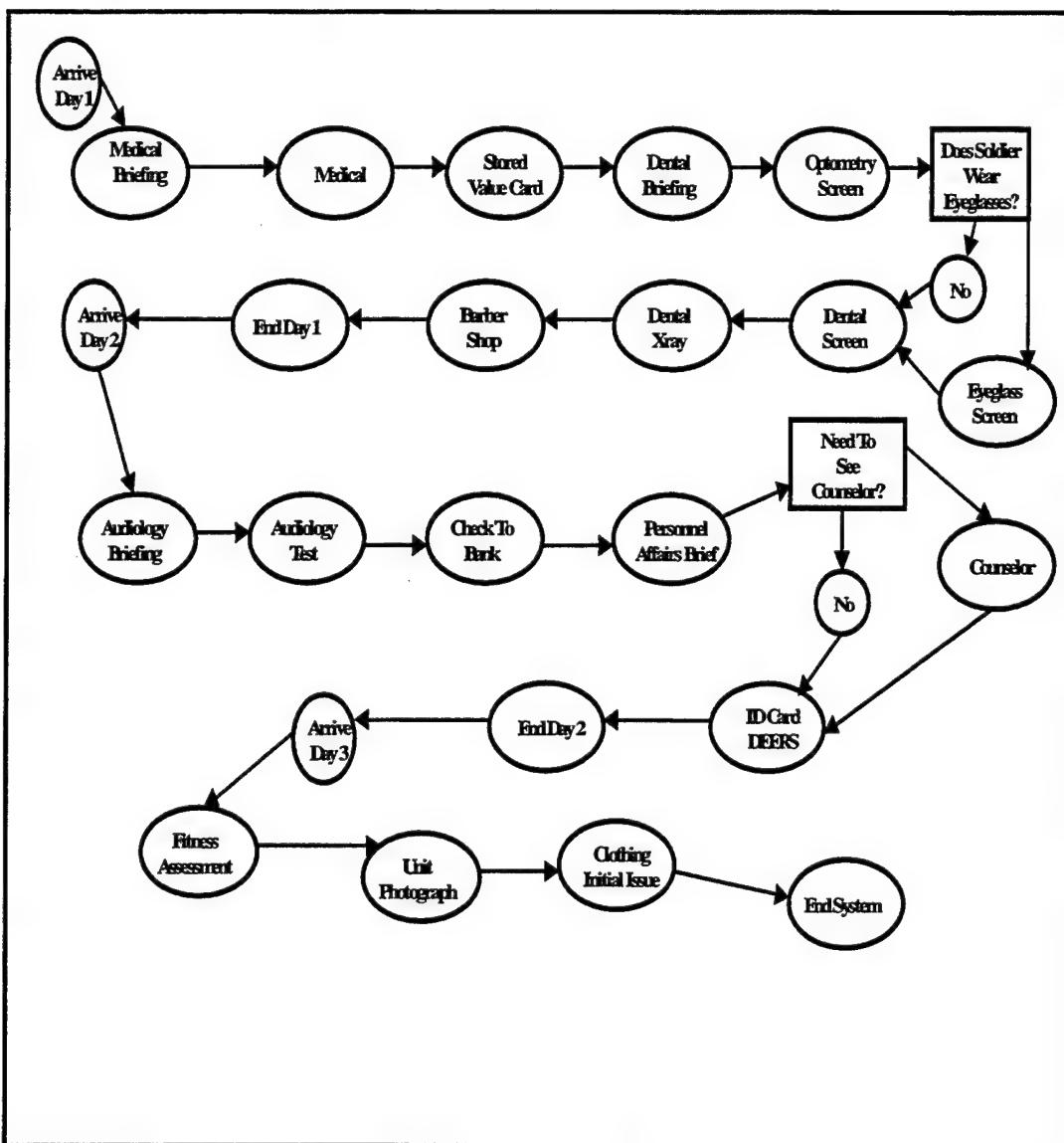

Figure 17.   Modified Event Flow

The modified simulation was run for the top 32 policy options previously identified. The results indicate that though some improvement in system day to day "on-

time" throughput occur with the recommended quick-fix changes, the number of stations scheduled for the first day remains a significant problem. Figure 18 depicts the results of the modified simulation with the quick-fix recommendations.

Servers								System Time	End System	End Day 1	End Day 2	Extra Day	Extra 2 Days	Extra 3 Days
Increase	M	SV	D	B	A	C	ID	(hours)	on time	on time	on time	required	required	required
0	1	1	1	2	1	5	1	34.6	361.0	214.7	195.5	185.6	228.3	225.2
1	1	1	1	2	1	5	2	24.4	923.1	214.7	530.6	76.9	0.0	0.0
1	1	1	1	2	1	6	1	34.6	361.0	214.7	195.5	185.6	228.3	225.2
1	1	1	1	3	1	5	1	34.6	361.0	214.7	195.5	185.6	228.3	225.2
2	1	1	1	2	1	6	2	24.4	923.2	214.6	530.2	76.9	0.0	0.0
2	1	1	2	2	1	5	2	24.4	924.4	215.6	531.8	75.7	0.0	0.0
2	1	1	1	3	1	5	2	24.4	923.1	214.7	530.6	76.9	0.0	0.0
3	1	1	1	2	1	7	2	24.4	923.1	214.6	530.2	76.9	0.0	0.0
3	1	1	2	2	1	6	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
3	1	1	1	3	1	6	2	24.4	923.2	214.6	530.2	76.9	0.0	0.0
4	1	1	1	2	1	8	2	24.4	923.1	214.6	530.2	76.9	0.0	0.0
4	1	1	2	2	1	7	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
4	1	1	1	3	1	7	2	24.4	923.1	214.6	530.2	76.9	0.0	0.0
5	1	1	2	2	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
5	1	1	1	3	1	8	2	24.4	923.1	214.6	530.2	76.9	0.0	0.0
5	1	2	1	2	1	8	2	24.4	923.1	214.6	530.2	76.9	0.0	0.0
6	1	1	2	3	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
6	1	2	2	2	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
6	2	1	2	2	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
7	1	2	2	3	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
7	1	3	2	2	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
7	2	1	2	3	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
8	1	3	2	3	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
8	2	2	2	3	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
8	2	3	2	2	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
9	2	3	2	3	1	8	2	24.4	924.0	215.6	531.7	76.0	0.0	0.0
9	1	3	2	3	2	8	2	24.4	927.8	215.7	533.4	72.3	0.0	0.0
9	2	2	2	3	2	8	2	24.4	927.8	215.7	533.4	72.3	0.0	0.0
10	2	3	2	3	2	8	2	24.4	927.8	215.7	533.4	72.3	0.0	0.0
10	2	3	2	3	1	8	3	23.8	948.0	215.7	585.1	52.0	0.0	0.0
10	1	3	2	3	2	8	3	23.8	947.0	215.7	583.6	53.1	0.0	0.0
11	2	3	2	3	2	8	3	23.8	947.0	215.7	583.6	53.1	0.0	0.0

Figure 18. Modified Simulation Output Reflecting Top 32 Policy Options

This modification yields significant increases in total "on-time" throughput as well as "on-time" throughput for the second day of in-processing. However, throughput for the first day is only slightly increased. Thus, this modification does not reconcile the problem of system backlog on the first processing day due to over-scheduling of stations. This indicates that there is potential for further analysis of the current system structure directed toward reducing blocks that occur on the first processing day. In the future the USAFATC should address changing the system as it currently stands.

E. SUMMARY

This chapter demonstrates the use of simulation to evaluate a current "real world" problem. It identifies policy options to improve the current system and ranks them in terms of cost and throughput. Additional information concerning the functionality of the system not previously identified by the client was also gleaned from careful scrutiny of the model results. From this information a quick-fix recommended improvement to the current system was explored by modifying the simulation model. Analysis of this recommended solution suggests that the client consider re-evaluating the system structure as currently configured. Additionally, the client should also consider prioritizing what stations to schedule on specific days. Thus, by providing a recommendation on where an increase in manpower would best improve system throughput, this study additionally provides the client with input on flaws in his system that have been overlooked for many years.

VI.   RECOMMENDATIONS AND CONCLUSIONS

A. RECOMMENDED MODEL IMPROVEMENTS

The areas described below identify some improvements to this model that would allow a more detailed analysis.

1. Data Collection

This model relies heavily on data provided by the client pertaining to service times. The sample sizes of these data sets were small, ranging from ten to thirty observations. There is no way to verify how clean the data implemented in this model is. 95% confidence intervals constructed for the means of the observed service times indicate that due to the small sample sizes, the estimated service times in the model could differ from the actual service times by as much as a factor of two. An extensive data collection effort over many in-processing periods and overseen by an independent observer drawing from greater sample sizes may provide better insight into the proper representation of service times in this model.

2. Soldier Flow

One of the assumptions this model makes is that of the "drill sergeant factor." The drill sergeant's primary responsibility is to ensure that each in-processing soldier is either "on-time" waiting for the next station to open, in a queue waiting for his turn for service at a station, or currently being served at a station. By making this assumption, the model effectively captures a conservative estimate of the total time the soldier spends in the system. This allows soldiers to remain in queue until they are served regardless of the time that station closes for business on a specific day. An improved way to model soldier flow would be to remove soldiers from station queues when the operating time for that

station for a specific day is complete, and then later in the simulation, during slack time, return that soldier to the station not previously completed. This would better replicate the initial surge of soldiers and possible backlog implications at the stations scheduled for the beginning of days two and three. It would also model the decisions made by a drill sergeant in accomplishing his primary tasks. The effect of this potential improvement was considered during model V&V by running the model for each day independently for selected policy options. The results of these runs did not significantly change any of our findings. However, including the drill sergeants decision-making process in the model would provide a greater level of resolution to the current model.

3. Attrition

Attrition was not included in this model due to lack of historical data available. However, soldiers in small numbers do attrit from the Reception Battalion during in-processing. An improvement to this model would be the data collection and implementation in the model of soldier attrition during in-processing due to lack of adjustment, physical fitness failure, or health reasons. Also, since they are held over for out-processing, they would occupy bed space thought to be available for in-processing soldiers.

4. Soldier Characteristics

This model has the framework to provide output regarding soldier characteristics such as what type of training (BCT or OSUT) the soldier is scheduled to attend following in-processing as well as soldier gender. Further improvements to the model along these lines could assist the USAFATC in predicting throughputs for the various training classes scheduled to begin in conjunction with the group of soldiers in-processing, as well as help predict gender

related housing requirements.

5. Human Factors

Human factors that may affect in-processing such as human error and mistakes, fatigue, apprehension, and excitement are not considered in this model. With an extensive data collection effort some of these factors could be captured and added to the current model. The inclusion of the human dimension would further enhance the real-world application of this model.

B. RECOMMENDATIONS FOR FURTHER RESEARCH

1. Ripple Effect Cost

An important consideration associated with soldiers not completing in-processing "on-time" is the cost associated with soldiers remaining at the Reception Battalion as "holdovers" after completing in-processing. This may occur because soldiers fail to complete in-processing prior to the next BCT or OSUT class start. These soldiers remain at the Reception Battalion in a "holdover" status until the next scheduled class begins which may keep them there for several weeks. The next group of arriving soldiers may lose seats to "holdovers" and thus become "holdovers" themselves. This effect may ripple over a period of months. The costs associated with this problem include empty seats in an OSUT or BCT class due to the original set of "holdovers" as well as the cost of soldiers remaining at the Reception Battalion waiting for the next class to begin which also effects available bed space.

2. Changes to the Current System

As discussed previously, Day 1 includes too many stations causing backlogs. This, in turn, causes soldiers to return to some stations on the second and third day of in-processing. Additional analysis is needed in this area to improve scheduling as well as improve utilization buildings and space used for in-processing.

C. CONCLUSIONS

This thesis investigated the current system used by the USAFATC to in-process new soldiers into the Army. The modeling and analysis of policy alternatives suggest the system may require restructuring in order to meet the demands placed on it during the "summer surge" time period. This study identifies feasible strategies for improving of the current system. Specifically, the results include recommendations to the USAFATC commander for increasing the number of servers at the ID Card in-processing station from one to two. This will lead to a substantial increase in "on-time" throughput at small cost.

This study also uncovered a long overlooked second-order problem with respect to USAFATC's structure of its soldier in-processing system. The system schedules too many stations the first day of in-processing resulting in system backlogs that degrade system efficiency. This is especially troublesome when confronted with drastic increased soldier arrivals during the "summer surge" period. In depth analysis of the effect of overloading the first day was not possible prior to the development of this model and made it possible to develop various policies for dealing with the surge period. In the past, the USAFATC only identified manpower shortfalls as the primary problem. The system is unaffected

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by this overloading throughout the majority of the year due to the steady flow of soldiers in much smaller sizes.

The model developed in this study answers specific questions regarding manpower policy options for the USAFATC. The comparison of the actual system and the recommended quick-fix change to the system illustrate how this model can be modified to explore additional alternatives. Additional studies considering system restructure and exploration of the effects of a less linear system on total "on-time" throughput are recommended for further exploration.

This thesis serves as a demonstration of the advantages of using simulation to solve a somewhat complex problem. Through simulation additional problem areas not previously addressed or identified can surface. The results of this study indicate that a small increase in manpower at one of the in-processing stations yields a vast improvement in system throughput at savings of up to $24,000 per week. Additionally, we illustrate previously unidentified problem areas in the structure of the current system that degrade its effectiveness during surge periods. Based on our analysis and implementation of our recommendation, the USAFATC has modified its system and reports an observable improvement of recruit "throughput" at its Reception Battalion.

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